

CPUC Energy Storage Use Case Analysis

Permanent Load Shifting (PLS)

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Contents

1. Overview Section	3
2. Use Case Description	3
2.1 Objectives	3
2.2 Actors	4
2.3 Proceedings and Rules that Govern Procurement Policies and Markets	4
2.4 Location	4
2.5 Operational Requirements	4
2.6 Applicable Storage Technologies	5
2.7 Non-Storage Alternatives for Addressing this Objective	5
3. Cost/Benefit Analysis	6
3.1 Direct Benefits	6
3.2 Other Beneficial Attributes	7
3.3 Costs	7
3.4 Cost-effectiveness Considerations	7
4. Barriers Analysis & Policy Options	8
4.1 Barriers Resolution	8
4.2 Other Considerations	9
5. Real World Example	9
5.1 Real-World Example 1: 1500 Walnut Street, Philadelphia, PA 14102	9
5.2 Real World Example 2: University of Southern California (USC), LA, CA	10
5.3 Real World Example 3: Redding Electric Utility, City of Redding, CA	10
5.4 Outstanding Issues	11
5.5 Contact/Reference Materials	12
6. Conclusion and Recommendations	12

1. Overview Section

Permanent Load Shifting (PLS) can provide a substantial benefit to the California electric grid by transferring load from congested peak times to over-generating off-peak times. Energy storage (ES) can play a critical role in PLS, but the proper market structures must be in place for storage to be widely implemented, and effectively monetize all the benefits it can provide to the grid.

Essentially any energy storage technology sited behind the meter (at the load) can effectively perform PLS. Historically thermal energy storage (TES) has played an active role, with over a Gigawatt of installed TES capacity worldwide. Energy storage used for PLS fits especially well with higher penetration of utility-scale wind generation, as a large amount of excess generation at night is not captured efficiently, if at all. In addition, a single energy storage system can be used to perform multiple different benefits with relatively little modifications, thereby greatly enhancing the value of the resource in general.

2. Use Case Description

This use case illustrates the benefits that energy storage can provide to the grid by performing permanent load shifting. PLS is defined as “routine shifting from one time period to another during the course of a day to help meet peak loads during periods when energy use is typically high and improve grid operations in doing so (economics, efficiency, and/or reliability).”¹ In addition, this use case provides some solutions to the barriers that exist for implementation of storage performing PLS on the grid.

Energy storage is an excellent way to achieve permanent load shifting, allowing energy to be stored, in the form in which it will be used, during off-peak periods and used during peak periods. ES systems allow building owners to run their buildings’ air conditioning during the peak periods using energy created and stored during off-peak periods, often times resulting in megawatt-hours of energy shifted.

2.1 Objectives

The objective of PLS is to provide many benefits to utility companies, system owners, the environment and the grid in general. The owner of the system will lower their energy costs over time by utilizing the lower time of use (TOU) electricity rates and will reduce their peak electric demand charges by shifting power use from on-peak to off-peak. The owner also gains flexibility in their system with backup capacity in the event of on-site or grid-scale malfunctions or disasters.

The utility can benefit from ES performing PLS in many ways. One significant advantage is the ability to defer electricity generation and transmission system infrastructure costs. The generation and transmission systems are designed to handle the absolute maximum peak load for the grid, and shifting power from peak to off-peak helps eliminate the need for added capacity. ES specifically benefits the transmission grid because the energy is stored at the

¹E3, Strategen Consulting, *Statewide Joint IOU Study of Permanent Load Shifting*, 2010

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user's end of the grid and is consumed locally. PLS also allows the utilities to lower their greenhouse gas emissions and fuel consumption by allowing the use of the most efficient and greenest generation resources when excess capacity is available during off-peak hours. Peaking energy generation facilities are also typically the least efficient and largest producers of greenhouse gases, therefore reducing the daily peak reduces greenhouse gas emissions.

2.2 Actors

It is important to recognize that ownership models can vary greatly. Customer, utility, and third-party ownership are all viable options, depending on the specific case.

<i>Name</i>	<i>Role description</i>
Building Owner/Manager	Property owner seeking to reduce electricity peak price and/or demand charges due to HVAC operation.
Utility	Electric utility for the building/resource that sets the pricing schedules for energy and power.
System Vendor/Installer	Provider/developer/installer/integrator of the system. These roles may all be played by one or many companies. Contractual agreements will vary significantly from ownership, to maintenance contracts, to turnkey installation.
Third Party Operator	Third party operators can be used as the conduit between consumers of energy and the grid operator.

2.3 Proceedings and Rules that Govern Procurement Policies and Markets for This Use

<i>Agency</i>	<i>Description</i>	<i>Applies to</i>
CPUC	AB2514	
Utility Tariffs	TOU and Demand Charge Tariffs	Participant
FERC	Orders 745 and 755	Participant
CPUC	Permanent Load Shifting Program	Participant/Aggregator

2.4 Location

An energy storage resource performing PLS will be located on the customer side of the electric meter, but could be customer, utility, or third-party owned. The physical location in relation to the end-use facility may vary, however. For instance, a district energy storage system would likely be located somewhere on the campus it serves, while a residential or small commercial system might be packaged with the air conditioning unit on the roof of, or adjacent to the building that it serves. For a battery system, the storage system equipment will be generally co-located with the electric service entrance equipment.

2.5 Operational Requirements

For the purposes of this use case, the energy storage asset must be able to discharge

during a significant portion of—if not all—peak hours, and charge during off-peak hours. This can be accomplished through a programmable interface to allow the system to absorb and discharge energy during the appropriate periods throughout the daily cycle. It should also be supplementing or replacing some form of conventional on-peak load and shifting the load to off-peak hours.

In addition, one significant advantage of energy storage systems over conventional resources is the ability to relatively simply add control systems and capacity to perform additional grid functions such as responding to grid events.

2.6 Applicable Storage Technologies

50+ MWh is listed as the maximum capacity, but the capacity is realistically constrained by how much air conditioning energy the building or campus requires during their peak periods.

<i>Storage Type</i>	<i>Storage capacity</i>	<i>Discharge Characteristics</i>
Thermal Energy Storage	This is primarily driven by the load of the facility or building, though there are three main classes: » Chilled water storage: 750kWh – 50+MWh » Ice on coil, internal melt: 33kWh – 50+MWh » Direct expansion thermal energy storage: 33kWh – 50+MWh	Fast and Medium response, long duration. At least enough discharge to cover the peak period of the day.
Battery Energy Storage	This is primarily driven by the load of the facility or building.	Fast response, short to long duration. At least enough discharge to cover the peak period of the day.
Flow Battery Energy Storage	This is primarily driven by the load of the facility or building. Provides ability to customize power and energy independently.	Medium response, medium to long duration. At least enough discharge to cover the peak period of the day.
Mechanical Energy Storage (e.g. Compressed Air Energy Storage)	This is primarily driven by the load of the facility or building.	Fast to medium response, short to long duration. At least enough discharge to cover the peak period of the day.

2.7 Non-Storage Alternatives for Addressing this Objective

The primary alternative to energy storage PLS is on-site generation, which is much more costly due to fuel and maintenance costs of diesel generators. Alternatively, renewables could be used for onsite generation, but this would still require storage to firm or time-shift

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generation for use during critical peak times. Renewables would not in any way assist in capturing excess grid generation during off-peak hours. Regular load shedding may achieve the peak reduction, but will not add demand when it is needed during off-peak hours.

3. Cost/Benefit Analysis

3.1 Direct Benefits

<i>End Use</i>	<i>Primary/ Secondary</i>	<i>Benefits/Comments</i>
1. Frequency regulation	S	Can do this with minor additional capacity and controls
2. Spin	S	Can do this with minor additional capacity and controls
3. Ramp	S	Can do this with minor additional capacity and controls
4. Black start	S	Can do this with minor additional capacity and controls
5. Real-time energy balancing	S	Can do this with minor additional capacity and controls
7. Resource Adequacy	P	This flows naturally from storage used as PLS
10. Supply firming	S	Can do this with minor additional capacity and controls
11. Peak shaving: load shift	P	This is a primary use of energy storage for PLS
12. Transmission peak capacity support (deferral)	S	This flows naturally from storage used as PLS
14. Transmission congestion relief	S	This flows naturally from storage used as PLS
15. Distribution peak capacity support (deferral)	P	This flows naturally from storage used as PLS
17. Outage mitigation: microgrid	S	Can do this with minor additional capacity and controls. For instance, TES systems are often used as emergency cooling for data centers.
18. TOU energy mgt	P	This is the primary method of performing PLS
20. Back-up power	S	*Electrical and mechanical storage only. Can do this with minor additional controls

3.2 Other Beneficial Attributes

<i>Benefit Stream</i>	<i>Y/N</i>	<i>Assumptions</i>
Emergency backup cooling/flexibility (*Thermal Energy Storage Only)	Y	Example: Dallas Ft. Worth Airport has a 10 million gallon thermal energy storage tank for their district cooling system. During an ice storm in February of 2012 which caused rolling blackouts, the airport kept their chillers turned off for ten days and only used chilled water from their TES tank for their air conditioning needs. This helped reduce demand on a compromised grid, helping the grid operator while the power lines were being repaired. Thermal energy storage can provide flexibility in unexpected times of man-made and natural disasters.
Reduced Emissions	Y	Excess off-peak generation is not used efficiently, and tends to be renewable (wind), whereas on-peak generation tends to be the most costly and inefficient. If you reduce peak generation needs by capturing renewable off-peak generation, you reduce overall emissions.
Distributed Flexible Resources	Y	Distributed resources create a more robust and efficient grid.

3.3 Costs

Energy storage projects vary greatly in terms of cost per MWh greatly depending on a variety of factors, including:

- » Capacity required – Many economies of scale are gained when the energy storage requirement increases
- » District cooling ΔT – This is specific to a chilled water thermal energy storage tank
- » Siting – The cost of an ES system can be impacted by the site preparation work needed before the installation
- » Aesthetic requirements – Often times ES systems are installed for universities, hospitals, government buildings, etc. where aesthetics require architectural treatment that can impact cost

<i>Cost Type</i>	<i>Description</i>
Installation	Greatly varies
O&M	Varies by technology type, but typically negligible

3.4 Cost-effectiveness Considerations

One place to begin is the E3/Strategen Consulting Statewide Joint IOU Study of Permanent Load Shifting

The cost effectiveness calculation should consider the overall societal and ratepayer perspective, as well as the end-user perspective. Avoided cost benefits provided by PLS include:

- » Electrical energy losses
- » Ancillary services
- » System generation capacity
- » Transmission and distribution capacity
- » Environmental costs
- » Avoided renewables energy purchases
- » Over-generation
- » Renewable integration²

4. Barriers Analysis & Policy Options

4.1 Barriers Resolution

The largest barrier is the risk and payback for the energy storage system owner. Reducing uncertainty through standard offers, and sharing risk among stakeholders through incentives, time of use rates, and demand charges are very effective methods to encourage the implementation of energy storage to perform PLS on the grid. Once implemented, it is clear that energy storage provides substantially more value to the grid than the alternatives.

<i>Barriers Identified</i>	<i>Barrier? Y/N</i>	<i>Policy Options / Comments</i>
System Need	Y	Expected changes to the load shape means that future PLS needs are likely to change.
Cohesive Regulatory Framework	N	Existing PUC programs address this for PLS.
Evolving Markets	Y	Standard offers for PLS are not yet a part of the marketplace, while TOU rates and demand charges tend to vary greatly among tariffs. Expected changes to the load shape means that future PLS needs are likely to change.
Cost Effectiveness Analysis	Y	The E3/Strategen Consulting paper begins this analysis, but parties have asked for further consideration.
Cost Transparency & Price Signals	Y	A standard offer and new tariffs would greatly improve transparency and price

²E3, Strategen Consulting, *Statewide Joint IOU Study of Permanent Load Shifting*, 2010

<i>Barriers Identified</i>	<i>Barrier? Y/N</i>	<i>Policy Options / Comments</i>
		signals. Load shape changes in the future complicate this.
Commercial Operating Experience	N	<p><i>What is the barrier?</i> Many technologies do not have sufficient operating experience to reduce costs and promote investment by utilities.</p> <p><i>How is it a barrier?</i> New technologies find it difficult to compete with incumbent technologies that have less technology risk.</p> <p><i>What are the potential resolutions?</i> Incentivize field demonstration. Help to define path to commercialization.</p>
Interconnection Processes	N	

4.2 Other Considerations

It should be noted that PLS is a purely behind-the-meter application, but all ownership models can apply (Customer owned, third-party owned, and utility owned).

5. Real World Example

5.1 Real-World Example 1: 1500 Walnut Street, Philadelphia, PA 14102

Tenants in the office building at 1500 Walnut St. in Philadelphia PA were concerned about their comfort as the existing HVAC system was in disrepair and was inefficient. The owner and engineers investigated many cooling systems and ultimately chose hybrid cooling with an IceBank™ thermal energy storage system. The hybrid system was designed as a permanent load shift and it was installed without disrupting the current tenants. The system has 1,300 ton hours of cooling capacity³ and can output for 4 hours at 160kW, or for 6 hours at 120kW⁵

With new DR programs in place in the regional transmission operator (RTO) PJM's jurisdiction, the operation of the hybrid TES cooling system were upgraded to allow the system to provide capacity when called upon by grid operators. Additional control systems and capacity were installed to allow the system to participate in PJM's Distributed Resource Markets, in addition to performing load shifting for the building. This increased the system's value both to the grid, and the system owner.

Owner/Manager	Gene O'Donnell
Utility	Exelon/PECO
System Vendor/Installer	Kevin Keenan, Account Manager. Tozour TRANE
Third Party Operator	Viridity Energy (a PJM-approved third party operator that

³ 14 CALMAC IceBank™ model 1098 tanks located in the basement of the building

	builds customized demand-side management software solutions that are based upon the unique operations of both the customer and the local and regional grid.)
Energy Storage Provider	CALMAC Manufacturing, Inc.
Location	1500 Walnut Street, Philadelphia, PA
Operational Status	Operational
Ownership	Commercial
Primary Benefit Streams	Peak Shaving/Load Shift, Resource Adequacy, Transmission Operation
Secondary Benefits	Time Of Use Energy Management
Contact	Electric Power Research Institute 3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA 800.313.3774 • 650.855.2121

5.2 Real World Example 2: University of Southern California (USC) in Los Angeles, CA

A 3 million gallon thermal energy storage (TES) tank built in 2003 for the University of Southern California (USC) in Los Angeles, CA operates with a chilled water temperature of 40° F and a warm water temperature of 56° F, providing a ΔT of 16°F. The storage capacity in Ton-hours with these parameters provides about 30,000 Ton-hours of cooling capacity. Assuming a chiller and cooling tower combined efficiency of 0.75 kW/Ton, this equates to 22,500 MW-hours of energy storage. The peak flow rate in the TES tank allows 6000 Tons of cooling capacity (up to 4.5 MW) to be shifted from peak to off-peak.

Owner/Operator	University of Southern California
Utility	Southern California Edison
System Vendor/Installer/Energy Storage Provider	DN Tanks
Location	University of Southern California, Los Angeles, Ca.
Operational Status	In operation since installment in 2003
Ownership	University of Southern California
Primary Benefit Streams	Energy cost savings via load shifting
Secondary Benefits	System flexibility
Available Cost Information	The TES portion of the project was just a part of the overall infrastructure construction, and was not specifically priced out.

5.3 Real World Example 3: Redding Electric Utility, City of Redding, CA

Redding Electric Utility (REU) has entered into a utility scale 6 MW distributed thermal energy storage contract with Ice Energy Holdings Inc. to offset commercial and industrial businesses refrigerant based air conditioners throughout their service territory.

Based on 7 years of product evaluations and pilot deployments, a completed city wide

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4500+ commercial building survey that identified 70MW of rooftop packaged air conditioning units within the utility service territory, and a detailed economical evaluation of peak capacity options available to serve the utilities 250 MW peak, REU selected Ice Energy's thermal energy storage peak capacity solution.

REU's energy storage project integrates automated demand response capabilities and HVAC replacements that are managed from Ice Energy's SmartGrid web based & AT&T wireless network system. This enables the utility to control the Energy Storage off peak charge and on peak discharge cycles as well as the Automated Demand Response loads. REU has contracted with Ice Energy to service the equipment long term. Ice Energy offers 25 year service contracts to ensure the product provides guaranteed operation health similar to other utility asset investments.

Unique to Ice Energy's water based energy storage battery, charge and discharge cycles do not degrade the systems cycle efficiencies or storage capacity over time. Because the Ice Bear product uses unfiltered tap water as its storage media, no hazardous materials are required with shipping and handling, installation, or servicing the product.

REU has taken this project two steps further in cooperation with Ice Energy and local businesses. Ice Energy contracts with local trades and local equipment suppliers for all project material and labor resources necessary to design and install the systems. REU projects 50% of their peak capacity investment is re-injected into the local community creating significant economic development opportunity's and job creation. REU and Ice Energy identified a local industrial manufacture that has begun assembling and testing the product locally further contributing to job creation for the City of Redding.

Owner/Operator	Redding Electric Utility
Utility	Redding Electric Utility
System Vendor/Installer/Energy Storage Provider	Ice Energy Holdings, Inc.
Location	Redding, Ca.
Operational Status	Begun product pilots in 2005 thru 2010, Begun utility scale deployment in 2011.
Ownership	Redding Electric Utility, Utility energy storage assets located on commercial and industrial properties
Primary Benefit Streams	Cost effective peak resource, grid system energy efficiency, substation and distribution feeder circuit peak relief, peak hedge.
Secondary Benefits	Dispatchable as aggregated or in alignment with distribution and substation grid infrastructure.
Available Cost Information	Less than \$2,000/kW turnkey project including services

5.4 Outstanding Issues

5.5 Contact/Reference Materials

EPRI Case Study on 1500 Walnut St. Project

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E3, Strategen Consulting, Statewide Joint IOU Study of Permanent Load Shifting, 2010.

6. Conclusion and Recommendations

Is ES commercially ready to meet this use?

Certain technologies are absolutely ready to meet this need, while others are still in development. There are definitely technologies that could be deployed immediately because they have proven to be cost effective and reliable.

Is ES operationally viable for this use?

Absolutely, as proven by the examples provided, among many others.

What are the non-conventional benefits of storage in this use?

The storage can be used more flexibly, and for more than just PLS with relatively little modification.

Can these benefits be monetized through existing mechanisms?

To a certain extent, TOU pricing and Demand Charges provide ways to monetize the benefits of PLS. However the systemic benefits are not yet fully captured in these mechanisms, therefore additional compensation frameworks should be established to fully compensate and incentivize PLS.

If not, how should they be valued?

There are a variety of approaches with varying pros and cons. The E3/Strategen Consulting study should be considered as a starting point to establish effective and fair compensation mechanisms.

Is ES cost-effective for this use?

Yes, especially when compared to the alternatives.

What are the most important barriers preventing or slowing deployment of ES in this use?

One of the major barriers is effective, clear, and consistent compensation and incentive frameworks at the utility and system operator level. In addition, risk and uncertainty are major barriers to ES installation on the grid.

What policy options should be pursued to address the identified barriers?

Standard offers that account for both energy shifted and capacity available on peak will increase transparency and reduce uncertainty, while monetary incentives will provide an

impetus to install systems on the grid.

Should procurement target or other policies to encourage ES deployment be considered for this use?

Yes, procurement targets would be very effective in quickly and widely deploying ES PLS systems in California. In addition, a standard offer and new tariffs would provide powerful methods of establishing the framework to capture PLS capacity.

DRAFT